Original Research Article

Effect of land use on soil quality in Afaka forest northern guinea savannah of Nigeria

ABSTRACT

Land use changes from forest into cultivated ecosystems result in negative impact on soil structure and quality. The purpose of this study was to determine effect of land use on soil quality in Afaka forest northern guinea savannah of Nigeria. Land use systems, including natural forest and cultivated land were identified. Eighteen (18) composite disturbed and undisturbed samples were collected from depth of 0-5 and 5-10cm for analysis of soil properties in the laboratory using rigid grid procedure. Most physical and chemical properties show ariations in response to land use types and geomorphic positions. Results indicate that the soils had high degree of weathering potentials, low to moderate bulk density at 0-5cm depth values range between 1.42 to 1.49 Mg m^{-3} in forest and cultivated land, bulk density at 5-10cm depths had values ranging between 1.34 and 1.46 Mg m^{-3} for forest and cultivated land respectively. The highest soil moisture contents at 0-5cm depth were 4.20, 2.63 cm^3/cm^3 , while at 5-10cm depths values were 4.32 and 2.13 cm^3/cm^3 recorded under forest and cultivation land use. The pH (H_2O) ranged from 6.9 to 7.16 in the land uses. The CEC of 8.60 cmol kg^{-1} and 8.54 cmol kg^{-1} was recorded on forest and cultivated land uses, the total nitrogen content of 1.21 g kg^{-1} and 1.11 g kg^{-1} for forest and cultivation land uses was recorded. The highest available phosphorus of 8.78 mg kg^{-1} and 5.47 mg kg^{-1} was recorded under cultivated and forest land uses. Results indicate that soil fertility parameters were moderate to low in soils of cultivated land and all slope positions, suggesting that soil fertility management is required in order to make agriculture sustainable on Afaka area

Introduction

Soil quality is defined as the capacity of a specific soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Brady and Weil, 1999). Thus, soil quality assessment reflects biological, chemical and physical properties, processes and their interactions within each resource unit (Karlen *et al*., 2001)

Over the last decade, soil quality has been one of the topics of great interest in Soil Science, so much so that a database such as the Soil Science CAB Database (CAB International Publishing) supplies more than 1500 publications that use the term 'soil quality' as a key word. Interests have been focused on defining the concept of soil quality and searching for reliable ways for assessing the quality of soils. In recent years, defining soil quality has put into consideration the key involvement of the soil in crop production, water and atmospheric purification and thus emphasis is laid on the role of the soil both for production and for environmental quality improvement. This has led to a profusion of definitions of soil quality, but that of Karlen *et al*. (1997).

Land use-induced changes in nutrient availability may influence secondary succession and biomass production (Foster *et al*., 2003) and reduce soil organic carbon (SOC) which plays a crucial role in sustaining soil quality, crop production and environmental quality (Doran and Parkin, 1994). Such changes directly affect soil physical, chemical and biological properties such as soil water retention and availability, nutrient cycling, gas flux, plant root growth and soil conservation (Gregorich *et al*., 1994). Maintenance of SOC is especially important due to its effect on soil nutrient status and structural stability.

MATERIALS AND METHOD

Site description

The study area is Afaka forest reserve, established in 1946, situated some 24 kilometers north – west of Kaduna and is roughly bisected by Kaduna-Tegina road (Figure 1). The area lies between Latitude 10^0 37^0, N and Longitude $07^0 15^0$ E, near milestone 132 south of the road and currently covers an area of 129 ha (FDRF 1964).The altitude is approximately 1950 ft (585 m) above sea level. The area is undulating slope to the south. Drainage is generally imperfect due to the occurrence of compacted or indurate layers in the subsoil (FDRF, 1964). The mean annual rainfall is between 1011-1161 mm; which is received mainly between May to September, with peak rainfall in August (Oluwasemire and Alabi, 2004).

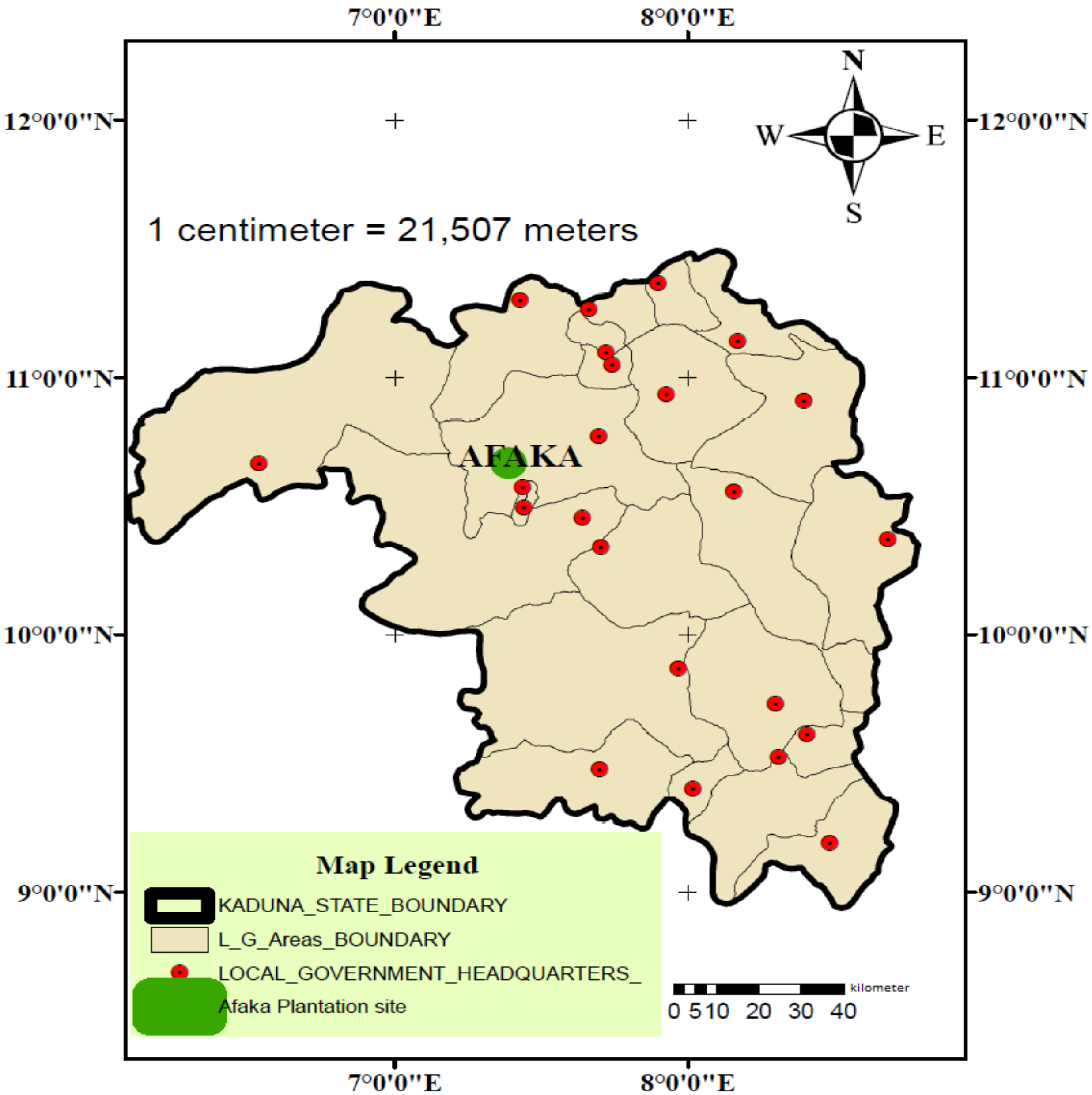

Figure 1: Map of Kaduna State showing Afaka forest reserve

Sampling plan: Soils on geomorphic positions (upper, middle and lower slope) were sampled on a rigid grid detailed survey plan; eighteen composite samples was use for laboratory analysis.

Soil samples from the 0- 5 cm soil depth and 5 -10 cm 100 m interval were collected along traverses on cultivated land and in adjacent forest, in each delineated geomorphic position (upper, middle and lower slope) for the forest and cultivated of the study area. The sampling area covered 1x1 km^2 the traverses were perpendicular to the baseline. Natural features such as roads were chosen as the baseline (Figure 2). In all, ten traverse lines were established, the sampling locations were selected based on identified typical Afaka forest vegetation, and typic-toposequence and area converted into crop cultivation.

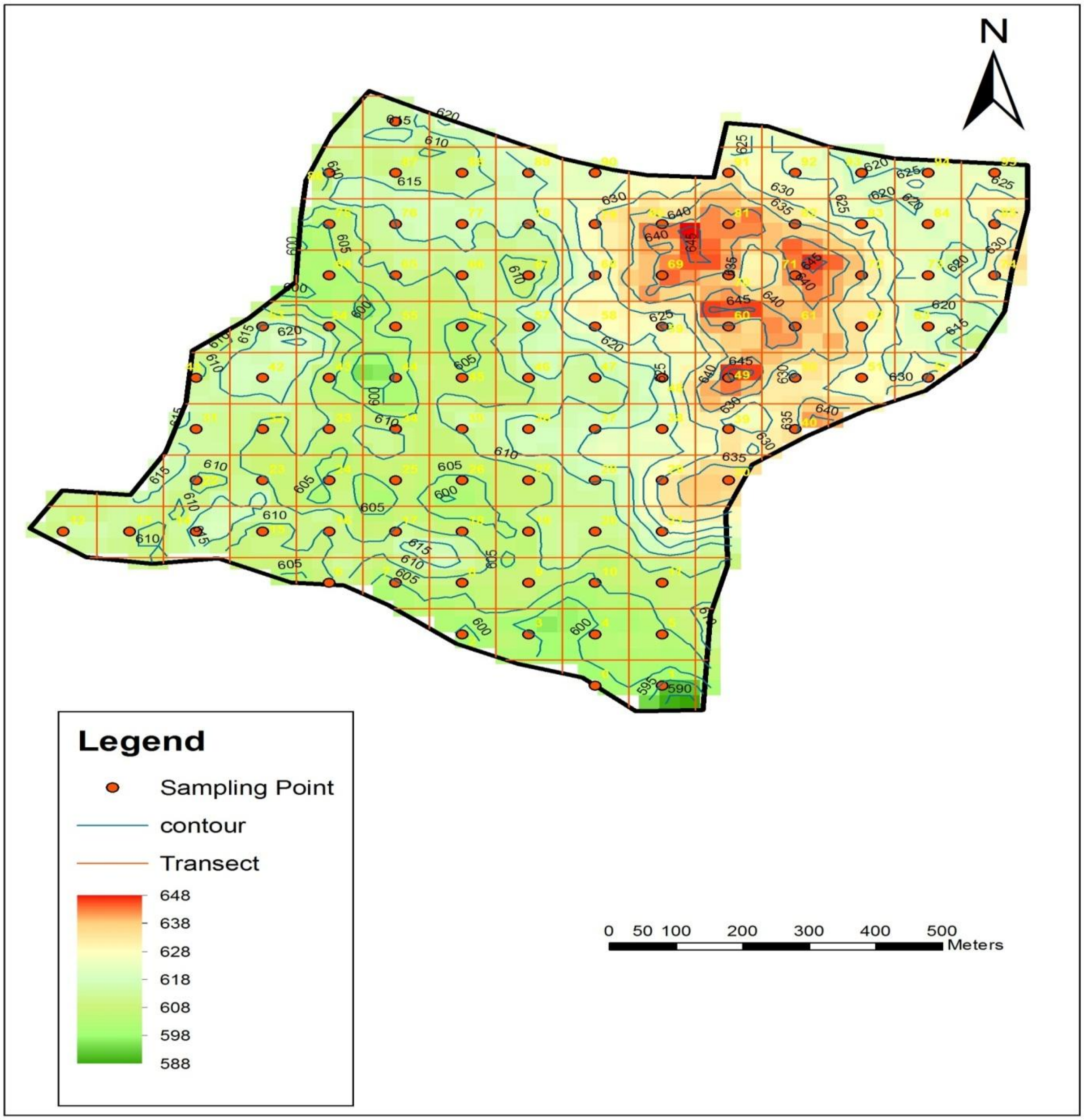

Fig 2: Map Showing Soil Geomorphic Positions and Sampling point in Afaka Forest Reserve

Laboratory analysis

Particles Size Distribution

Particle size analysis of soil samples was used to determine percentage of sand, silt and clay in the soil samples. These percentages were used to determine textural classes of soil samples. The analysis was performed using the hydrometer method (Gee and Or, 2002).

Aggregates stability indices

Composite soil samples previously dried and wet-sieved through 5-mm mesh were used to calculate Macro-aggregate stability indices such as: Mean Weight Diameter (MWD), Water Stable Aggregates (WSA) and Degree of Aggregation (DOA) (Kemper and Rosenau, 1986; Zhang *et al.*, 1996)

Determination of bulk density

Three undisturbed soil core samples were collected with metal cylinders that measured 45 mm diameter and 50 mm height from the designated soil depths, (0-5 and 5-10 cm) at three geomorphic units (upper, middle and lower slopes) in each of the two land use types, for the determination of bulk density (Blake and Hartge, 1986).

Bulk volume was obtained by measuring internal diameter and height of the cylinder, so that volume of the soil was expressed as:

$V = \pi r^3 h$ Where

V is volume of the core (cm3), r is the radius (cm), h is the height of the core and π is 3.142

Bulk density was calculated as:

$$\rho_p \quad = \quad \frac{weight\ of\ oven\ dry\ soil}{volume\ of\ soil} \quad (\frac{g}{cm^3})$$

Determination of soil pH

Soil pH of each soil sample obtained from auger points was determined both in water and 0.01M$CaCl_2$ solution, using a soil to solution ration of 1:2.5 (Rhoades, 1982)

Organic carbon

Soil organic carbon was determined by the Walkley-Black wet oxidation method by (Nelson and Sommers, 1982).

Cation exchange capacity (CEC)

The cation exchange capacity (CEC) was determined in the soil samples by ammonium acetate (1N NH4OAc) at pH 7.0,

Total Nitrogen

The total nitrogen determination was done using macro Kjeldahl method as described by Bremner (1982).

Available phosphorus was determined by Bray-1 extraction method (Bray and Kurtz, 1945).

Soil quality evaluation

Soil quality evaluation was based on the soil management assessment framework (SMAF) suggested by Andrews *et al*. (2004), scoring functions for 14 potential soil quality indicators (Wienhold *et al*., 2009). A general guideline has been the use of minimum of five indicators with at least one each for biological, chemical and physical properties or process (Karlen *et al*., 2011) as suggested by Larson and Pierce (1992); a minimum data set (MDS) was established. The MDS selected in this study include soil functions such as ease of tillage, salinity support for plant growth, bulk density (BD), CEC, total N, available P, and exchangeable K were used as indicators for plant growth support, while organic carbon was indicator for biological activity in the soil and MWD to assess erodibility of the soils. Indicators were divided into three, more is better was applied to N, P, K and organic matter, while less is better which applied to bulk density, optimum is better which applied to pH (Larson and pierce 1994).

Indexing soil quality indicators

The indexing of soil quality indicators is due to temporal and spatial variability of soil, complexity of an ecosystem and differences in soil management practices. Andrews *et al.* (2001) postulated that once the systems management goals are identified, soil quality indexing involves three main steps, namely, choosing appropriate soil quality, transforming indicators' scores and combining indicators…

i. Choosing appropriate soil quality indicator for minimum data set
ii. Transforming indicators score
iii. Combining indicators the scores into the index.

Choosing appropriate soil quality indicators for a minimum data set

The important step in indexing soil quality indicators is to choose appropriate soil quality indicators to efficiently and effectively capture the effect of critical soil functions as determined by management goals for which the evaluation is being made. Larson and

Pierce (1994) proposed a minimum set of data which is the smallest set of soil properties or indicators needed to measure soil quality, identifying key soil properties or attribute that are sensitive to change in soil functions established a minimum data set

Table 1 show Soil quality indicators selected for minimum data set and its function

Indicators of soil condition	**Relationship to soil condition and function**
Less is better	**physical**
Texture	Retention and transport of water and chemical,
Bulk density and infiltration	Potential for leaching ,productivity and erosivity
Water holding capacity	Related to water retention ,transport and erosivity, available water texture and organic matter
Indicator more is better	**chemical**
Soil organic matter	Fertility and stability
Electrical conductivity	Plant and microbial activity
Extractable N, P, and K	Plant loss available and for N
Optimum is better	**biological**
pH	Biological and chemical activity threshold
Potentially mineralization	Soil productivity and N supplying potential
Soil respiration, water content and temperature	Microbial activity

(Larson and Pierce, 1992).

Transforming indicators score

This involve selecting MDS for assessing a particular management objective, Karlen *et al.*,(2001) explained that this step is required so that biological, chemical and physical indicator measurement with totally different measurement unit can be combined. Andrew and Carol, (2001) emphasized simplicity of design and use by developing a linear scoring techniques that relies on the observed of data to determine the highest possible score for each indicator and non-linear score technique involve the use of curve linear scoring functions with a y-axis ranging from 0 to one and x axis representing a range of site of function

a) More is better: total nitrogen, cation exchange capacity organic carbon content microbial biomass
b) less is better: bulk density
c) optimum is better: porosity electrical conductivity, water filled pore space phosphorus, pH, would electrical conductivity Anikwe (2006)

Statistical Analysis

Analysis of variance (ANOVA) test was done to determine significant differences among treatments. Significant mean differences were separated with the least significant difference (LSD) at 0.05% level of probability using the statistical analysis software (SAS) SAS (1997). Correlation analysis was also used to determine the level of relationship between soil properties and the land uses.

RESULTS AND DISCUSSION

Bulk density

The significant BD was under cultivated land at depths 0-5 cm (1.49 Mg m^{-3}) followed by 5-10 cm (1.46 Mg m^{-3}), under forestland. In contrast, the low BD values at 0-5 cm (1.42 Mg m^{-3}) and 5-10 cm (1.34 Mg m^{-3}) were observed under forestland. Results of soil analyses on bulk density (BD) of different land use are presented in Table 2. High bulk density under cultivated lands was attributed to trampling effects, continuous cultivation and soil surface sealing/ crusting. Odunze (2012) observed that bulk density rapidly increased with depth in the surface, but remained uniform at depths >20 cm and bulk densities tend to increase with depth primarily due to lack of organic matter and aggregation. Islam and Weil (2000) observed that Forestland had lower bulk density than cultivated land and attributed it to restricted movement of machine at the forested land compared to continuous cultivation of the cultivated land. Forest litter and roots' decompose over time to improve quality of surface soils and reduce bulk density. Evrendilek *et al*. (2004) also reported that conversion of forestland into cultivated land during a 12-year period increased bulk density and decreased total porosity. The result also shows that bulk density decreases with slope. The variation of soil bulk density among slope gradients might be attributed to variation of disturbance of soil particles by erosion. Suspended finer particles are transported down the slope where they accumulate at the bottom; thus increasing the clay and silt contents at the bottom slope positions with higher micro porosity and lower bulk density (Midkiff *et al.*, 1985).

Available moisture content

Available moisture content was determined at two depths (0-5 cm and 5-10 cm). Result shows that forest retained water content of 4.20 cm^3/cm^3 at 0-5 cm and 4.32 cm^3/cm^3 at 5-10 cm, while the lowest water content of 2.82 cm^3/cm^3 at 0-5 cm and 2.79 cm^3/cm^3 at 5-10 cm were observed under cultivated land (Table 2).. The interaction of water retention with slope shows that middle slope soils have water content of 4.50 cm^3/cm^3 followed by middle slope cultivated but statistically similar with lower and upper slope forest, but significantly different for upper and lower slope cultivated. This confirms that cultivation deteriorates soil structural aggregation and reduces soil water retention capacity (Wakene, 2001). Soil retention at field capacity (FC) for all land use systems show decrease in trend with depth (Wakene, 2001). Considering land uses on different topographic positions, greater water retention of forestland was observed in soils of middle slope positions. This difference in water content was attributed to effect of soil type, position on topography and organic matter content. Natural forest soils have more available water holding capacity compared to cultivated lands (Ayoubi, 2011).

Table 2: Effects of Land Use and Slope on Dry and Wet Mean Weight Diameter,bulk density, and available moisture content.

	Bulk density (Mg m^{-3}) 0-5cm	(Mg m^{-3}) 5-10cm	AMC 0-5 cm(cm^3/cm^3)	5-10 cm (cm^3/cm^3)	dmwd	wmwd
Land use						
forest	1.42[a]	1.34[a]	5.96	5.79	1.19	1.19
cultivation	1.49[a]	1.46[a]	3.17	3.84	1.24	1.27
SE±	0.05	0.06	0.2	0.33	0.08	0.12
Cultivated slope						
upper	1.43	1.40[a]	1.3	1.6	1.22	1.00
middle	1.46	1.40[a]	4.2	3.2	1.04	1.51

lower	1.36	1.23^{a}	2.3	1.5	1.32	1.05
Forest slope						
upper	1.50	1.53^{a}	4.03	4.06	1.21	1.36
middle	1.46	1.43^{a}	4.5	5.53	1.18	1.04
lower	1.50	1.40^{a}	4.06	3.36	1.31	1.36
SE±	0.06	0.06	0.28	0.03	0.10	0.15

AMC= available moisture content, dmwd =dry mean weight diameter and wmwd =wet mean weight diameter

low mean values may be most vulnerable to wind erosion due to low dry stable aggregates (Ogunwole and Ogunleye, 2004). Increasing intensity of cultivation can reduce carbon rich macro-aggregates and increase carbon depleted micro-aggregates, resulting in an overall loss of soil organic carbon (Six *et al.,* 2000). Conventional ploughing; which is commonly practiced in Afaka areas, causes damage to soil structure. Noellemeyer *et al.* (2008) reported a loss of intermediate aggregate size classes after long term cultivation with more pronounced negative effects of cultivation on macro aggregate size classes. This finding supports that the conversion of native forest to cultivation leads to deterioration of soil structure (Tisdall and Oades, 1980) as was applicable to Alfisols in Afaka forest reserve in Northern Guinea savanna of Nigeria.

Dry means weight diameter (dmwd)

Forestland had mean dry aggregate fractions of 1.24 mm; while cultivated land had 1.19 mm cultivated land has 1.22 mm, 1.04 mm and 1.32 mm for upper, middle and lower slopes. Similarly, forestland had 1.21 mm, 1.18 mm and 1.31mm for upper, middle and lower slopes respectively depth of 0 -10 cm (Table 2). This implies a negative impact of tillage on aggregate size distribution when compared with values in forest land use. Dry aggregate size distribution is one of the major physical characteristics of soil that strongly affects soil quality, fertility and its resistance to erosion and degradation and is also considered an indicator of soil structure (Odunze *et al.,* 2013)

Wet mean weight diameter (WMWD)

.Cultivated land recorded 1.19 mm; which was lower than forested land with 1.26mm. Similarly, cultivated land recorded 1.00 mm, 1.51 mm and 1.05 mm for upper, middle and lower slopes while forest recorded 1.36 mm, 1.04 mm and 1.36 mm for upper middle and lower slopes respectively at depth of 0-10cm (Table 2). The mean water stable aggregates were highest at forest than cultivated land though not statistically significant ($p > 0.05$). The low wet MWD recorded in cultivated land may be associated with degradation of large macro-aggregate fractions in the dry soil when immersed in water (Unger, 1997)

Table 3: Effects of Land Use and Slope on, Total Nitrogen, Available Phosphorus, Exchangeable Sodium Concentration, cation exchange capacity

	TN (g kg^{-1})	AP (mg kg^{-1})	Na (cmol kg^{-1})	CEC (cmol kg^{-1})
Land use				
forest	1.2	8.78	0.44	8.60
cultivation	1.1	5.4	0.45	8.54
SE$\pm$	0.01	2.1	0.04	0.5
Cultivated slope				
upper	1.1	9.60	0.43	7.93

middle	1.4	3.2	0.51	9.56
lower	0.9	13.4	0.41	8.13
Forest slope				
upper	1.4	8.82	0.39	9.00
middle	1.4	5.01	0.48	9.00
lower	0.9	2.45	0.43	7.80
SE±	0.41	2.57	0.05	0.60

TN = total nitrogen, AP = available phosphorus, Na = sodium and CEC = cation exchange capacity.

Total nitrogen

Total N contents were highly affected by the different land use systems. Total soil nitrogen at 0-10 cm depth had mean of 1.11 g kg^{-1} under cultivated land, while 1.2 g kg^{-1} was recorded under natural forest land, cultivated land had mean of 0.9 g kg^{-1}, 1.4 g kg^{-1} and 1.05 g kg^{-1} of total nitrogen for upper, middle and lower slopes respectively, while forestland had mean of 1.4 g kg^{-1}, 1.4 g $kg^{-1}$and 0.9 g kg^{-1} total nitrogen in upper, middle and lower slopes respectively (Table 3). Iwara *et al*. (2011) reported that presence of vegetation affords the soil adequate cover, thereby reducing loss in macro and micro nutrients that are essential for plant growth and energy fluxes. The total nitrogen status was low in cultivated land and high under natural forest land use in Afaka northern guinea savanna of Nigeria. Ayoubi *et al*. (2011) reported that natural forest soils had more total nitrogen compared to cultivated lands. Heluf and Wakene (2006) reported highest total N on surface soil layers of virgin lands compared to cultivated and fields. Total nitrogen decreased consistently with depth under land use systems corresponding to the findings of Gong *et al*. (2005), Geissen and Guzman (2006) and Alemayehu (1990).

Available phosphorus (AP)

Available phosphorus (AP) concentration of land use systems had mean values of 8.78 mg kg^{-1} and 5.47 mg kg^{-1} for forest and cultivated land, Lower slopes recorded 13.4 mg kg^{-1} available phosphorus, followed by upper slope with 9.60 mg kg^{-1} and middle slope with 3.2 mg/kg in cultivated land. Forestland at upper slopes recorded 8.82 mg kg^{-1} available phosphorus, followed by middle slope with 5.01 mg kg^{-1} and lower slope with 2.45 mg kg^{-1} in (Table 3). Thomas (2000) reported that natural forestland contained relatively higher concentration of AP as a result of high organic matter turnover in soils, which released phosphorus during its mineralization and is in conformity with findings from this study. The difference in available phosphorus might be due to increased clay and reduced organic matter concentration in cultivated land. Organic compounds in soils increase P availability by the formation of organophosphate complexes that are more easily assimilated by plants, anion replacement of H_2PO_4 from adsorption sites, the coating of Fe/Al oxides by humus to form a protective cover and reduced phosphorus fixation (Thomas, 2000). Also, decomposing of organic matter releases acids that increase solubility of calcium phosphates (Ahn, 1993; Thompson and Troeh, 1993; Havlin *et al*., 1999). Available P was positively correlated with organic carbon (Thomas, 2000).

Differences of slope gradient among the areas did not significantly ($P > 0.05$) affect available P (Table 3). The lowest (4.12 mg kg^{-1}) and highest (9.31 mg kg^{-1}) contents of available P were recorded in soils of middle slope and upper slope terrains respectively (Table 3). Fisseha *et al.* (2014) also reported low available P within soils having low content of OM, but Nega and Heluf (2013) stated that available P content of Tropical soils did not necessarily decrease with decrease of organic matter. The low contents of available P observed in soil of the study area were in agreement with reports by some authors (Murphy and Lugo, 1986; that availability of P under most soils of savanna Alfisols decline by the impacts of fixation, abundant crop harvest and erosion.

Cation exchange capacity (CEC):

Forestlands recorded CEC value of 8.60 cmol kg^{-1} compared to cultivated land with mean value of 8.54 cmol kg^{-1} while the lower slopes in forestland showed decrease in CEC with 7.80 cmol kg^{-1} and 9.00 cmol kg^{-1} for upper and middle slope respectively. The upper slope of cultivated land showed decrease in CEC with 7.93 cmol kg^{-1}, 9.56 cmol kg^{-1} for middle slope and 8.13 cmol kg^{-1} for lower slope (Table 3). Cation exchange capacity (CEC) of soil is a very important indicator of soil fertility or at least of potential soil fertility, nutrient availability and could indicate the organic matter content of soil. There was variation in CEC of soils under the two land use types and slopes (Table 3). Cation exchange capacity (CEC) of the study area was not affected by land use. Woldeamlak and Stroosnijder (2003) reported higher CEC value in soils under natural forest than soils under cultivation. Bhaskar *et al.* (2005) reported lower CEC values obtained in cultivated land and could be partly attributed to erosion, nature of soils and low organic matter content of the soils.

Soil pH (H_2O) **and $CaCl_2$**

The highest soil pH in water (pH 7.16) was recorded in forestland and pH 6.9 in cultivated land.

The upper slope had pH (H_2O) 6.9, middle slope had pH (H_2O) 6.9 and lower slope had pH (H_2O) 6.8 in cultivated land, while forestland had pH (H_20) 7.2, 6.9 and 7.2 for upper, middle and lower slopes respectively. Values of soil pH ($CaCl_2$) were 6.49 and 6.22 for forest and cultivated land use types respectively. Upper slopes had pH ($CaCl_2$) 6.13; middle slope had pH

($CaCl_2$) 6.16 and lower slope had pH ($CaCl_2$) 6.36 in cultivated land, while 6.5 pH ($CaCl_2$), 6.3 pH ($CaCl_2$) and 6.6 pH ($CaCl_2$) values were recorded in forest land (Table 4). It however increased slightly down the topographic positions in soils of both cultivated and forested lands. The generally increasing trends in pH value from middle to lower slope positions may be due to higher deposition of basic cations in lower slope positions. This agrees with Belay (1996), Abayneh (2001) and Mohammed *et al*. (2005) who independently reported low pH value in soils of high altitude and steeper slopes are associated with washing out of solutes from these parts.

Table 4: Effects of Land Use and Slope on pH in water and in $CaCl_2$

	pH (H_2O)	pH ($CaCl_2$)
Land use		
forest	7.16	6.49
cultivation	6.90	6.22
SE$\pm$	0.1	0.12
Cultivated slope		
upper	6.9	6.13
middle	6.9	6.16
lower	6.8	6.36
Forest slope		
upper	7.2	6.5
middle	6.9	6.3
lower	7.2	6.6
SE$\pm$	0.12	0.14

Criteria for Soil Quality Monitoring and Evaluation in Afaka reserve, Nigeria

To monitor soil quality, treatment means for bulk density, mean weight diameter, pH in H_2O and $CaCl_2$, organic carbon, total nitrogen, available phosphorus, cation exchange capacity were matched as shown in the Table 5.

Bulk density shows that forest soil had the least bulk density 1.34 Mg m^{-3} while cultivated land had the highest bulk density 1.46 Mg m^{-3} (Table 5).

Table 5 shows that mean weight diameter dry for forest soil (1.24mm) is greater than for cultivated land (1.19mm). The pH in H_2O and $CaCl_2$ shows that pH decreased slightly under cultivation and increased under forest. Both pH in H_2O and $CaCl_2$ followed the same trend. Table 5 shows that there was increase in organic carbon contents under forest (10.2 g kg^{-1}) while cultivated land show decrease in organic carbon content (8.21 g kg^{-1}). Also, Table 5 shows that a total N content of (1.2 g kg^{-1}) was observed in the forestland, while cultivated land was with 1.1 g kg^{-1}.

Table 5 shows that forestland had the highest content of available P (8.78 mg kg^{-1}), Cultivated land had the least (5.47 mg kg^{-1}) and this could be attributed to crop uptake of phosphorus since it has been proven that legumes use up phosphorus more and the presence of legume facilitates the utilization of soil phosphorus by crops in the low P soil of Northern Guinea Savanna of Nigeria Thomas (2000).

Cation Exchange Capacity (CEC) decreased slightly under cultivation (8.54 cmol kg^{-1}), and increased slightly with forest 8.60 cmol kg^{-1} in CEC would imply that soil health/quality over the years had been positively impacted upon by the management practices (McRae and Mehuys, 1988; Carlson and Huss-Danell, 2003). Table 5 shows that lower slope had the least bulk density (1.37 Mg m^{-3}) while upper had the highest bulk density 1.47 (Mg m^{-3} then 1.44 (Mg m^{-3}) record in the middle slope, it’s also shows that there was increase in organic carbon contents under middle slope 11.0 g kg^{-1} fallowed by upper slope with 9.30 g kg^{-1} then lower slope 7.40 g kg^{-1}. Total N content of 1.20 g kg^{-1} was observed at upper slope, 1.4 g kg^{-1} and 0.9 g kg^{-1} at middle and lower slope respectively.

Table 5 shows that upper slope had the highest content of available P among the other slopes, this could be attributed to crop uptake of phosphorus and the presence of legume facilitates the utilization of soil phosphorus by crops in the low P soil of Northern Guinea Savanna of Nigeria (Kalm *et al*. 2002). It shows that CEC decreased slightly under lower slope 7.97 cmol kg^{-1}, 8.46 cmol kg^{-1} at upper slope and increased under middle slope 9.28 cmol kg^{-1} . Table 5 shows that lower slope increased in dry mean weight diameter with 1.32mm while upper slope had 1.22 mm. Lower slopes show least in wet mean diameter (1.19 mm) and upper slope (1.21mm), middle slope shows increase with (1.28 mm) table 5. It shows that pH in water decreased slightly under middle slope and increased under lower slope. Decrease in soil pH however, was not sufficient to hamper crop growth. Both pH in H_2O and $CaCl_2$ did not followed the same trend. Management practices which were superior by improving soil quality were ascertained from results and a summary of the threshold limits using soils that were superior as a baseline is presented in Tables 5.

Table 5: Threshold limits for soil quality assessment in Afaka Alfisols Using Minimum Data Set

Soil parameter	**Forest**	**Cultivated land**
Bulk density (Mg m^{-3})	1.34	1.46
Organic carbon (g kg^{-1})	10.2	8.21

Total nitrogen (g kg^{-1})	1.2	1.1
Available phosphorus (mg kg^{-1})	8.78	5.47
CEC (cmol kg^{-1})	8.60	8.54
Dry mean weight	1.24	1.19
Wet mean weight	1.27	1.19
pH (H_2O (1:2.5)	7.16	6.90
pH ($CaCl_{2)}$ (0.01M)	6.49	6.22

Table 6: Threshold limits in this study for soil quality assessment in Afaka Alfisols

Properties	upper	middle	lower
Bulk density (Mg m^{-3})	1.47	1.44	1.37
Organic carbon (g kg^{-1})	9.30	11.0	7.40
Total nitrogen (g kg^{-1})	1.20	1.4	0.9
Available phosphorus (mg kg^{-1})	9.31	4.12	7.94
CEC (cmol kg^{-1})	8.46	9.28	7.97
Dry mean weight	1.22	1.11	1.32
Wet mean weight	1.21	1.28	1.19
pH (H_2O (1:2.5)	7.03	6.97	7.08
pH ($CaCl_{2)}$ (0.01M)	6.38	6.37	6.32

Table 7: Threshold limits for soil quality assessment in Afaka Alfisols.

Properties	upper	middle	lower
Bulk density (Mg m^{-3})	1.47	1.44	1.37
Organic carbon (g kg^{-1})	9.30	11.0	7.40
Total nitrogen (g kg^{-1})	1.20	1.4	0.9
Available phosphorus (mg kg^{-1})	9.31	4.12	7.94
CEC (cmol kg^{-1})	8.46	9.28	7.97
Dry mean weight	1.22	1.11	1.32
Wet mean weight	1.21	1.28	1.19
pH (H_2O (1:2.5)	7.03	6.97	7.08
pH ($CaCl_{2)}$ (0.01M)	6.38	6.37	6.32

Soil quality evaluation

Soil of the land uses and slopes were cumulatively rated for quality base on the SMAF protocol and the results are shown in Table 8. Each of the indicator values was divided by a common denominator (highest possible measurement for indicator in the land uses and slopes plus 10 % of it) before being subtracted from 1 (in the case of parameters for which less is better). There is the tendency for indicator with lower denominator to have higher value than indicator with higher denominators. These explain variability in the individual scores for different indicators.

When cumulatively put together however, upper forest soil had the highest score index followed by cultivated lower slope soil, cultivated upper, middle forest, forest lower and cultivated lower slope land respectively. The variation order of soil (upper forest>lower cultivated>upper cultivated>middle forest>lower forest>middle cultivated) indicate the direction of good quality of soil.

Table 8: Soil Quality Monitoring and Evaluation in Afaka forest, Nigeria

	Soil of Afaka	forest and cultivated land use	
Soil parameter	High	medium	low
Bulk density(Mg m^{-3})	≥ 1.4	1.2– 1.4	< 1.2
Organic carbon (g kg^{-1})	> 15	10 – 15	< 10
Total nitrogen (g kg^{-1})	0.3	0.2-0.3	<0.2
Available phosphorus(mg kg^{-1})	≥ 4.0	2.5 – 4.0	< 2.5
CEC(cmol kg^{-1})	>8.0	7.0 – 8.0	< 7.0
Dry mean weight	≥1.5	1.3 – 1.5	< 1.3
Wet mean weight	≥1.5	1.3 – 1.5	< 1.3
pH (H_2O(1:2.5)	>5.5	4.8 – 5.5	< 4.8
pH ($CaCl_2$) (0.01M)	>4.5	4.0 – 4.5	< 4.0

Note: > is greater than, < less than, ≥ greater than or equal to, ≤ less than or equal to

Combining the indicators scores into the index

This involves developing scoring function for each individual soil quality indicator and transforming the score into dimensionless values thus ranking them into a specified numerical value (Anikwe 2006). Each individual indicator is combined with several other indicators in the minimum data set to form a set of soil quality indicator to evaluate a soil for specified applied practical purpose (Anikwe 2006). It is important to note that for each indicator, a scoring function and realistic baseline and threshold value. The values for the scoring function are either neither specific for a kind of land use for specific kind of sol quality evaluation for specific management practice (Anikwe 2006). Therefore soil quality rating is calculated by summation of weight scores for each of soil function.

Table 9: combining indicators the scores into the index (SMAF protocol)

Functions	Indicators	F upper	F middle	F lower	C upper	C middle	C lower
Ease of tillage	Bulk density	0.015	0.014	0.015	0.014	0.014	0.013
Biological activities	Organic matter	0.12	0.12	0.123	0.087	0.096	0.06
Support plant growth	Total N	0.014	0.014	0.009	0.011	0.014	0.009
Support plant growth	Available p	0.08	0.05	0.024	0.096	0.032	0.134
Plant nutrient	CEC	0.09	0.09	0.078	0.079	0.095	0.081
Resistance to air erosion	Dry mean weight	0.012	0.012	0.013	0.012	0.010	0.013

Resistance to water erosion	Wet mean weight	0.013	0.010	0.013	0.01	0.015	0.010
Salinity	pH (H_2O(1:2.5)	0.072	0.062	0.072	0.069	0.069	0.068
Salinity	pH ($CaCl_2$) (0.01M)	0.065	0.063	0.066	0.061	0.061	0.063
	Total (Index)	0.481	0.435	0.413	0.439	0.406	0.451

Soil quality was assessed using a score scale of 1 to 6; where 1 is rated best and 6 rated worst. Thus; upper forest with highest total score was rated best, while middle cultivated with lowest total score rated worst. Upper forest scored best and enhance soil quality conditions (optimum soil organic carbon , total nitrogen , available phosphorus, potassium, EC, and bulk density), while middle slope cultivated lands were rated worst (low organic carbon, low k, moderate phosphorus, moderate nitrogen, low bulk density and electrical conductivity (Table 10)

Table 10: Ranking of soil quality under different land use and slopes

Slope positions	Total score	Percentage	Ranking
F upper	0.481	48.1	1
C lower	0.451	45.1	2
C upper	0.439	43.9	3
F middle	0.435	43.5	4
F lower	0.413	41.3	5

C middle	0.406	40.6	6

A score scale of 1 to 6 was used in the assessment of parameters; where 1 is best and 6 is the worst condition.

5.1. Summary

The study was conducted with the aim to determine effect of land use on selected physical and chemical properties of Alfisols in Guinea savanna and to suggest management practices that would sustain croplands for sustainable productivity conserve the environment and assess quantitatively, effect of forest and cultivation land uses on soil carbon stock. Rigid grid detailed survey plan was employed. Undisturbed core soil samples from depth of 0- 5 cm (top soil) and 5-10 cm (lower layer) were collected at auger points determined along traverses from cultivated land and in adjacent forest, in each delineated geomorphic position of the study area for water retention potential, and bulk density. Other soil samples collected were used for wet and dry aggregate stability determinations and selected chemical properties. The sampled area covered 1 km by 1 km dimension and the different locations were selected based on identified typical Afaka forest vegetation, typic-toposequence and crop cultivated sites. Data collected was analyzed with SAS software (SAS, 1997) computer package to test for significant difference among treatments. In conditions where there was significant difference, mean comparison was performed with least significant different (LSD). However, saturated hydraulic conductivity and dry and wet aggregate stability were statistically not affected by these treatments ($p<0.05$). The results also show that soil moisture content was significantly affected ($p<0.05$) by land use type and slope and soil carbon stock show significant difference in land use type. The results also show no significant difference between these land use types and slope positions ($p<0.05$) on cation exchange capacity, total nitrogen, available phosphorus, Soil quality evaluation was based on the soil management assessment framework (SMAF) suggested by Andrews *et al*. (2004), scoring functions for 14 potential soil quality indicators (Wienhold *et al*., 2009) and a minimum data set (MDS) was established. The MDS selected in this study include soil functions such as ease of tillage, salinity support for plant growth, bulk density (BD), CEC, total N, available P, and exchangeable K were used as indicators for plant growth support, while organic carbon was indicator for biological activity in the soil, MWD was used to assess erodibility of the soils. Alfisol at the upper forest land had better soil quality than those at the slope positions. Slight change in CEC would imply that soil health/quality over the years had been positively impacted upon by the management practices.

5.2. Conclusion

From the study, it was concluded that soil physico-chemical properties significantly varied among land use systems and slope positions in the study site. Shift in land use systems from natural forest to agricultural land use systems had detrimental effect on soil physical and chemical properties. The result indicates that organic matter concentration declined particularly in the upper slope of cultivated land, when compared to forest land. The result also indicates impact of forest on compaction of soils by the relatively high bulk density values recorded in soils under cultivated land use type on almost all the topographic positions. However, slope position affected most selected soil properties under different land use types considered in this study. The study indicates that cultivation led to increased bulk density, porosity and sodium content, reduced organic carbon, aggregate stability and water retention, total nitrogen, available phosphorus and potassium compared to forest land. The soil quality management should address the problem of land degradation which will help in mitigating the effects of climate change and global warming.

Forest soils have excellent potentials for sequestering organic carbon and maintaining or improving soil quality indicators; such as, bulk density, aggregate stability, soil moisture content, soil organic carbon content and soil structure. Lower soil bulk density and pH levels, higher level of soil aggregation and lower susceptibility to wind and water erosion were observed on the cultivated land.

5.3 Recommendations

It is recommended that integrated land management should be practiced such as practical soil conservation policies and measures to ensure sustainable use of soil as a resource to combat the ongoing soil changes and improve soil fertility in different land use systems to overcome land degradation and achieve sustainable agricultural production in the study area.

Further studies involving longer term research and evaluation of land uses for carbon sequestration in soil aggregate fraction potentials, as well as socio-economics of the system is suggested. This would allow for better discernment of soil quality changes and cost benefits of the system.

Long-term experiments (10–30 years) should be conducted to establish the positive and negative effects of different land uses on soil indicators for developing models so that appropriate action could be taken accordingly

Reference

Abayneh, E. (2001). Some physicochemical characteristics of the Raya valley soils. *Ethiopia Journal of Natural Resources,* 3(2): 179-193.

Agbenin, J.O. (1995). Laboratory manual for soil and plant analysis (selected methods and data analysis).Aggregate and Particle Associated Organic Carbon under Different Land Uses in Nepal. *Soil Science Society of America Journal*, 71(4): 94-1203.

Ahmad, W. and Khan, F. (2009). Managing soil fertility for sustained crop productivity on eroded lands of District Swabi. Ph.D. Thesis, Department of Soil and Environmental Sciences, Agricultural University, Peshawar. 161-169.

Ahn, P. M. (1993). Tropical soils and Fertilizer use. Intermediate tropical agriculture serious. Malaysia: Long man Group UK Limited *America Journal,* 68: 1945-1962.

Alemayehu, T., (1990). Soil and irrigation management in the state farms. pp. 47-52. In *Proceeding of the first Natural Resource Conservation Conference.* Natural Resource Degradation, a Challenge to Ethiopia, 7-8 February 1989. Addis Ababa, Ethiopia. Institute of Agricultural research (IAR).

Amezketa, E. (1999). Soil aggregate stability: A review *Journal of Sustainable Agriculture*, 14:83-151

Anderson, J.M. and Ingram, J.S.I. (1993). Tropical Soil Biology and Fertility: A Handbook of Methods (2nd ed.). C.A.B. International Wallingford, U.K. page 221**.**

Andrews S. S., Karlen, D. L. and Cambardella, C. A. (2004) The soil management assessment framework: A quantitative soil quality evaluation method. *Soil Science Society American Journal*, 68: 1945-1962.

Andrews, S. S. and Carrol C. R. (2001). Designing a decision tool for sustainable agroecosystem management: Soil quality assessment of a poultry litter management case study. *Ecological. Application,* 11 (6): 1573-1585.

Andrews, S.S., Karlen D.L. and Cambardella C.A. (2004). The soil management assessment framework: A quantitative soil quality evaluation method. *Soil Science Society of Nigeria*, 11 (6): 1573-1585

Angers, D. A., Edwards, L. M., Sanderson J. B. and Bissonatte, N. (1999). Soil organic matter quality and aggregate stability under eight potato cropping sequence in a find sandy loam of prince Edward island. *Canadian Journal of Soil Science,* 79:411-417.

Anikwe, M.A.N, Obi M. E, and Agbenin, N.N. (2003), Effect of crop and soil management practices soil compatibility in maize and groundnut plots in a Paleustult in southeastern Nigeria. *Plant and Soils*, 253:457-465

Anikwe, M.A.N. (2006) soil quality assessment and monitoring: A review of current research effort.

Ayoubi, S., Khormali, F., Sahrawat, K. L. and Rodrigues de Lima, A. C. (2011). Assessing the Impacts of Land Use, 87: 152–160

Belay T., (1996). Characteristics and landscape relation hip of Vertisols and Vertic Luvisol of Melbe, Tigray, Ethiopia. SINET: *Ethiopian Journal of Soil Science*, 19 (2): 93-1113.

Bhaskar, B.P, Butte P. S. and Brauah, U. S. (2005). Characterization of soils in the 'Bil' environments of Brahmaputra valley in Jorhat district, Assam for land use interpretation. *Journal of Indian Society of Soil Science,* 53**:** 3-10

Blake,G. R. and Hartge, K. H. (1986) Bulk density ,p 363-376 in A Klute (ed) *Method of Soil Analysis*, part 1 second edtion .As A monograph No 9 Madison, WI

Brady, N.C. and Weil, R.R. (1999). The nature and properties of soil.12th edition. Prentice Hall, New Jersey, USA.881

Brady, N.C. and Weil, R.R. (2002). *The Nature and Properties Of Soils, 13th Edition.* New Jersey, USA: Prentice- Hall Inc. 960.

Brar, G.S. and Unger, P.W. (1994). Soil temperature simulation with varying residue management. *Journal of Agronomy and Crop Science*, 172: 1-8.

Bray, K.H. and Kurtz, L.T. (1945). Determination of total organic and available forms of phosphorus in soils. *Soil Science Society of American Journal*, 59: 39-45.

Bremner, J.M. and Mulvaney, C.S. (1982). Nitrogen total. P.595-642. in A.L. Page et al. (ed.) *Methods of Soil Analysis*, Part 2. Chemical and microbiological properties. SSSA, Madison, Wisconsin.

Bronick, C.J., and R. Lal. (2005). Soil structure and management: a review. *Geoderma*, 124(1/2): 3–22.

Caravaca, F., Hernandez, T. Garcia, and Roldan, A. (2002). Improvement of rhizosphere aggregate stability of afforested semi-arid plant species subjected to mycorrhizal inoculation and compost addition. *Geoderma*, 108:133-144.

Carlson, G., and Huss-Danell, K. (2003). Nitrogen fixation in perennial forage legumes in the field. *Plant and Soil*, 253: 353- 372.

Çelik, I. (2005). Land use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. *Soil and Tillage Research, 83*: 270-277.

Denef, K., Six, J., Bossuyt, H., Frey, S, D., Elliot, E. T., Merckx, R. and Paustain ,K (2001). Influence of dry –wet cycles on the interrelationship between aggregate, particle organic matter, and microbial community dynamics. *Biology and Biochemistry of Soils*, 33:1599-1611

.Doran, J.W., Jones, A.J. (1996). Methods for Assessing Soil Quality. *Soil Science Society of America,* Special Publication, 49.

Doran, J.W. (2002). Soil health and global sustainability: translating science into practice. *Agriculture, Ecosystem and Environment,* 88: 119–127.

Doran, J.W. and Safely, M. (1997). Defining and assessing soil health and sustainable productivity. In:Pankhrust, C. *et al.* (Ed.). *Biological Indicators of Soil Health*. Wallingford, UK: CAB International. PP. 1-28.

Doran, J.W.and, Parkin, T.B., (1994). Defining and assessing soil quality. In: Doran, J.W., Coleman, D.C., Bezdicek, D.F., Stewart, B.A. (Eds.), Defining Soil Quality for a Sustainable Environment. Soil Science Society of America Special Publication, vol. 35. *Soil Science Society of America,* Madison, Wisconsin, pp. 3–21.

Doran, J.W., Zeiss, M. R., (2000). Soil health and sustainability: managing the biotic component of soil quality. *Applied Soil Ecology,* 15; 3–11.

Dudal, R. and Decaers, J. (1993). Soil organic matter in relation to soil productivity. pp. 377-380.

Evrendilek, F., Celik, I., and Kilic, C. (2004). Changes in soil organic carbon and other physical soil properties along adjacent Mediterranean forest, grassland, and cropland ecosystems in Turkey. *Journal of Arid Environment, 59*: 743-752.

Federal Department Of Forestry Resources (FDFR) Afaka (1964)

Fisseha, H. (2014). Study of phosphorus adsorption and its relationship with soil properties, analyzed with Langmuir and Freundlich models. *Agriculture, Forestry and Fisheries*, 3(1): 40-51.

Food and Agriculture Organization (FAO). (2006b). Plant Nutrition for Food Security: A guide for Integrated Nutrient Management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome, Italy

Foster, D., Swanson, F., Abler, J., Burke, I. Brokaw, N., Tillman D. and Knapp, A. (2003). The importance of land-use legacies to ecology and conservation. *Bioscience, 53: 77-88.*

Geissen, V., Guzman, G. M. (2006). Fertility of tropical soils under different land use systems-a case study of soils in Tabasco, Mexico. *Applied Soil Ecology, 31*; 169-178.

Gomez, A.A., Swete, D.E., Kelly, K.K. and Coughlan, K.J. (1996). Measuring sustainability of agricultural systems at the farm level. p401-409. *In*: Methods for Assessing Soil Quality, J.W. Doran and A.J. Jones (Eds); Special publication no. 49, *Soil Science Society of America*, Madison, USA.

Gregorich, E.G., C.M. Monreal, M.R. Carter, D.A. Angers and B.H. Ellert (1994). Towards a minimum data set to assess soil organic matter quality in agricultural soils, 75; 161-164.

Gregorich, E.G., Ellert, B.H., and Monreal, C.M. (1995). Turnover of soil organic matter and storage of corn residue carbon estimated from natural 13C abundance. *Canadian Journal of Soil Science*, 75: 161-164.

Havlin, J. L., Beaton, J. D., Tisdale, S. L. and Nilson, W. L. (1999). *Soil fertility and fertilizers: an introduction to nutrient management,* (6th ed.). Prentice Hall. Upper Saddle River, New Jersey

Haynes, R. J. and G.S. Francis (1993). Change in microbial C, soil carbohydrate composition and aggregate stability induced by selected crop and forage species under field condition. *Journal of Soil Science*, 44:665-675.

Heluf, G. and Wakene, N. (2006). Impact of land use and management practices on chemical properties of some soils of Bako area, western Ethiopia. *Ethiopian Journal of Natural Resources.* 8(2): 177-197.

Islam, K. R. and Weil, R. R. (2000). Land Use Effects on Soil Quality in a Tropical Forest ecosystem of Bangladesh. *Agriculture Ecosystem and Environment, 79(1): 9-16*.

Iwara, A. I., Ewa, E. E., Ogundele, F. O., Adeyemi, J. A., and Otu, C. A. (2011). Ameliorating Effects of Palm Oil Mill Effluent on the Physical and Chemical Properties of Soil in Ugep, Cross River State, South-Southern Nigeria**.** *International Journal of Applied Science and Technology, 1*(5), 106-112.

Karlen , D. L ., Andrews, S.S. and Doran, J.W., (2001). Soil quality: current concept and applications. *Advances in Agronomy* 74: 1-40

Krull E, Baldock J, and Skjemstad, J. (2001): Soil texture effects on decomposition and soil carbon storage. NEE Workshop Proceedings, 18-20 April 2001 CRC for Greenhouse Accounting, CSIRO *Land and Water Australia*.

Lal, R. and Stewart, B.A. (1995). Soil Management: Experimental Basis for Sustainability and Environmental Quality. *Advances in Soil Science,* CRC Press, Boca Raton, Florida.

Landon, J.R., (Ed.). (1991). Booker tropical soil manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474.

Larson, W. E. and Pierce, F. J. (1992). Soil loss tolerance: maintenance of long term sol productivity. *Journal of Soil and Water Conservation*, 39:136- 138

Larson, W. E. and Pierce, F. J. (1994). The dynamics of soil quality as a measure of sustainable management. Pages 37 - 51 in J. W. Doran, D. C. Coleman, D. F. Bezdicek and B. A. Stewart, eds. Defining soil quality for a sustainable environment. SSSA- Special Publication 35. *Soil Science Society of America*, Madison , WI, USA.

Materechera, S. A., Mkhabela, T. S. (2001). Influence of land-use on properties of a ferralitic soil under low external input farming in southern Swaziland. *Soil and Tillage Research, 62*: 15-25.

McRae, R.J., and G.R. Mehuys (1988). The effect of green manuring on the physical properties of temperate-area soils. *Advances in Soil Science*, 3: 71-94.

Midkiff, D.V., Frye, W.W. and Blevins. R.L. (1985). Soil erosion effects on soil properties and crop yield in farme's fields in Kentucky during 1983-84. American Society of Agronomy, Madison, WI, USA. 209p. mountain ecosystems. *Ecologie Soeiete Francaised' Ecologie; Paris; France* 29 (1-2): 393-398.

Mohammed A, Leroux, P.A.L., Barker, C.H. and Heluf G. (2005). Soils of Jelo micro-catchment in the Chercher highlands of Eastern Ethiopia: I. Morphological and physiochemical properties. *Ethiopian Journal of Natural Resources*, 7(1): 55-81.

Murphy, P.G. and Lugo, A.E. (1986). Ecology of tropical dry forests. *Annual Review of Ecology and Systematics*, **17**: 67-88.

Nega, E., and Heluf, G. (2013). Effect of land use changes and soil depth on soil organic matter, total nitrogen and available phosphorus contents of soils in senbat Watershed, Western Ethiopia. *Asian Research Publishing Network Journal of Agricultural and Biological Science,* 8(3): 206-212

Nelson, D.W. and L.E. Sommers (1982). Total carbon, organic carbon and organic matter In: AL. Page et al. (ed.). Methods of Soil Analysis, Part 2, 2nd ed. Agron. Mongr. 9, ASA and SSSA, Madison, W1. p539-577.

Noellemeyer, E., Frank, F., Alvarez, C., Morazzo, G., Quiroga, A. (2008). Carbon contents and aggregation related to soil physical and biological properties under a land-use sequence in the semiarid region of central Argentina. *Soil and Tillage Research,* 99; 179-190.

Nortcliff, S. (2002). Standardization of soil quality attributes. *Agriculture, Ecosystems and Environment,* 88: 161–168.

Odunze ,A.C.,Ebireri, O.F.,Ogunwole, J,O., Tarfa, B.D., and Eche, N,.M (2013). Effect of tillage and fertilizer on soil quality and yield of maize in an alfisol of a northern guinea savanna of Nigeria. *Journal of Agriculture and Biodiversity Research 167-177 2013*

Odunze A.C Soil conservation for mitigation and adaption to a changing climate: sustainablesolutions in the Nigerian savanna ecology *International Journal of Plant and Soil Science,* 8(4):1-12, 2015

Odunze, A.C., J. Wu, S. Liu, H. Zhu, T. Ge, Y. Wang, and Q. Luo (2012). Soil quality changes and quality status: A case study of the subtropical China Region Ultisols. *British Journal of Environment and Climate Change,* 2(1): 37-57.

Odunze, A.C., Kureh, I. (2006). Land use limitations and Management Option for a Savanna Zone Alfisols Proceedings of the 30th Annual conference of the *Soil Science Society of Nigeria,* held at University of agriculture, Markurdi, 5-9, December, 2006. Pp 54-64.

Offiong, R.A. and Iwara, A.I. (2012). Quantifying the Stock of Soil Organic Carbon Using Multiple Regression Model in Fallow Vegetation, Southern Nigeria. *Ethiopian Journal of Environmental Studies and Management,* 5(2): 166-172.

Ogunwole, J.O. and Ogunleye, P.O (2004). Surface aggregation, trace, and heavy metal environment under long-term application of farmyard manure and mineral fertilizers contamination in soil. *Soil Science and Plant Analysis,* 36(11 and 12): 1506-1516.

Oluwasemire, K. O. and Alabi S O (2004) Ecological impact of changing rainfall pattern, soil process and environmental pollution in Sudan and northern guinea savanna agro ecological zones of Nigeria. *Soil Resources* 5 pp 23-31.

Putman, J. and Alt, K. (1987). Erosion control: how does it change farm income *Journal of Soil and Water Conservation,* 42(4): 265-268.

Raji, B.A and Ogunwole J. O, (2006): Potential of soil carbon sequestration under various land use in the sub-humid and semi-arid savanna of Nigeria, Lessons from long term experiments. International Journal of Soil Science 2006, 1:33-43.regional perspectives. *American Journals Alternative to Agriculture*. 7, 12–16.

Reginold, E. M., Prmod, K. C, Dhyan, S. and Ashokk P. (2007). Soil quality response to long-term nutrient and crop management on a semi-arid Inceptisol. *Agriculture, Ecosystems and Environment*, 118(1-4), 130-142(Jan 2007)

Rhoades, J. D. (1982). In: page A.K, Miller R.H. and Kenny D.R. (eds). Methods of soil analysis, part 2, chemical and mineralogical properties second edition. *Agronomy,* 9: 159.

SAS Institute (1997). SAS/ETS User's Guide, Version 6, second Edition SAS Institute Inc., Cary, NC.

Seeber, J., and Seeber, G.U.H. (2005). Effects of land use changes on humus forms on alpine pastureland (Central Alps, Tyrol). *Geoderma*, 124:215-222

Shukla, M. K., Lal, R., & Ebinger, M. (2006). Determining Soil Quality Indicators by Factor Analysis. *Soil and Tillage Research, 87*: 194-204.

Six, J., K. Paustian, E.T. Elliott and C. Combrink, (2000). Soil structure and organic matter: I. Distribution of aggregate-size classes and aggregate-associated carbon. *Soil Science Society American Journal*, *64:681-689.*

Thomas, S. J. (2000). Soil fertility evaluation. *Sumner Handbook of soil science* (pp. 159-164), United States of America: CRC presses, LLC.

Thompson, L. M. and Troeh, F. R. (1993). *Soils and Soil Fertility* (5th edition.). Oxford University press.

Tisdall, J.M., Oades, I.M. (1980). The effect of crop rotation on aggregation in a red-brown earth. *Australian Journal of Soil Resources*. 18, 423-434.

Wakene N, (2001). Assessment of important physicochemical properties of Dystric Udalf Dystric Nitosol) under different management systems in Bako area, western Ethiopia. *M.Sc.Thesis, Alemaya University, Ethiopia. 93.*

Werner, M.R. (1997). Soil Quality characteristics during conversion to organic orchard management. *Applied Soil Ecology* 5:151-167.

Wienhold, B. J. Andrews S S and Karlen D. L., (2009). Soil quality: A review of the science and experiences in the USA. *Environment Geochemical*, *Health*. 26, 89-95.

Woldeamlak, B. and Stroosnijder, L. (2003). Effects of agro-ecological land use succession on soil properties in the Chemoga watershed, Blue Nile basin, Ethiopia. *Geoderma*, 111: 85-98.

Zhang W.L., Tian Z.X., N. and Zhang, X.Q. (1996). Nitrate pollution of groundwater in northern China. *Agriculture Ecosystems and Environment*, 59: 223–231